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AUTHOR Janicki, Terence C.; Peterson, Penelope L.
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ABSTRACT

This study investigated aptitude-treatment interaction (ATI) effects of variations in direct instruction. Two teachers each taught a 2-week fractions unit to two classes of fourth- and fifth-grade students. Each teacher taught one class using direct instruction and the other using a small-group variation of direct instruction. Students completed aptitude measures before the study began and achievement and attitude measures at the end. Regression analysis on achievement showed significant ATI and significant teacher effects. Students who had positive attitudes and an internal locus of control did better in the small-group variation, probably because they had some choice of activities and control over their learning. Teachers differed in effectiveness within direct instruction but did not differ within the small-group variation. (Authors)

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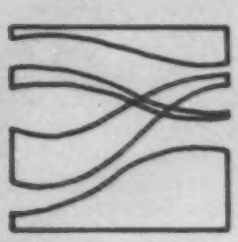

Technical Report No. 537

Aptitude-treatment Interaction Effects of Variations in Direct Instruction

by Terence C. Janicki and Penelope L. Peterson

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APTITUDE-TREATMENT INTERACTION EFFECTS OF VARIATIONS IN DIRECT INSTRUCTION

by

Terence C. Janicki and Penelope L. Peterson

Report from the Project on
Studies of Instructional Programming for the Individual Student

Penelope L. Peterson
Faculty Associate

Wisconsin Research and Development Center
for Individualized Schooling
The University of Wisconsin
Madison, Wisconsin

March 1980

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Abstract

This study investigated aptitude-treatment interaction (ATI) effects of variations in direct instruction. Two teachers each taught a 2-week fractions unit to two classes of randomly assigned fourth- and fifth-grade students. Each teacher taught one class using direct instruction and the other using a small-group variation of direct instruction. Students completed aptitude measures before the study began and achievement and attitude measures at the end. Regression analysis on achievement showed significant ATI and significant teacher effects. Students who had positive attitudes and an internal locus of control did better in the small-group variation probably because they had some choice of activities and control over their learning. Teachers differed in effectiveness within direct instruction but did not differ within the small-group variation.

This study investigated aptitude-treatment interaction (ATI) effects of variations in a direct instruction approach. Rosenshine (1979) has described a model of direct instruction that has the following dimensions: an academic focus; a teacher-centered focus; little student choice of activities; use of large groups rather than small groups for instruction; and use of factual questions and controlled practice in instruction. Based on the teaching effectiveness research, Rosenshine has argued that direct instruction is effective for increasing student achievement in reading and mathematics in the elementary grades. However, results of ATI research suggest that the effectiveness of a given instructional approach may depend on student aptitudes or characteristics (see, for example, Cronbach & Snow, 1977).

Ebmeier and Good (1979) investigated effects of student types, teacher types, and instructional approaches on mathematics achievement. They used a manual developed by Good, Grouws, Beckerman, Ebmeier, and Flatt (Note 1) to train 20 fourth-grade teachers in the direct instruction approach; 19 control teachers received no training. With the exception of the students in the educated/secure teachers' classrooms, all student types performed best in the trained teachers' classes. However, in the educated/secure teachers' classes, the high achieving/task-oriented students did better in the control teachers' classes. Although Ebmeier and Good observed the teachers' classes and documented that the trained teachers exhibited more of the behaviors characteristic

of direct instruction than did the control teachers, they did not really describe what was happening in the control teachers' classes. Thus, we might infer that in the educated/secure teachers' classrooms the added structure and constant teacher monitoring of direct instruction was detrimental to the high achieving/task-oriented students. But we do not know what was beneficial about the instructional approaches used by the control teachers.

We can, however, look to other ATI studies to discover aspects of instructional approaches that may benefit this type of student. According to Ebmeier and Good, these high achieving/task-oriented students were high on prior achievement and low on external motivation--dependence on external factors (such as checking of papers) for motivation in math. Results of an ATI study by Peterson and Janicki (1979) indicated that high achieving fourth-, fifth-, and sixth-grade students did better in math when they were allowed to work on seatwork in small mixed-ability groups rather than working alone. Results of other research has suggested that providing a choice of activities may be beneficial for students who are internal rather than external on locus of control and thus, attribute their successes and failures to internal rather than external factors (see, for example, Greene, Note 2).

This study investigated the interaction of student aptitudes with two treatments—a direct instruction approach and a small-group variation of the direct instruction approach. The treatments differed on two dimensions. First, in the direct instruction approach students worked on seatwork individually; in the small-group variation students

worked on seatwork in mixed-ability groups of four students. Second, in the direct instruction approach all students were given a homework assignment at the end of class. In the small-group variation students who completed their seatwork were given the choice of working on their homework or playing math games in their small groups. The aptitudes investigated were student ability, locus of control, preference for working in small groups, and attitude toward mathematics.[1]

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[1]In this study "aptitude" refers to "any characteristic of a person that forecasts his probability of success under a given treatment" (Cronbach & Snow, 1977, p. 6).

Method

Subjects

The study was conducted in an elementary school which was composed of multi-age units. The teachers in the fourth- and fifth-grade unit identified 117 students who had the necessary prerequisites for a unit on fractions. The teacher sent letters home with these students explaining the study. Two female teachers from the unit volunteered to participate in the study and were paid an honorarium for the extra time that the study required. Both teachers were experienced classroom teachers.

Ten days before the teaching began, students completed the Raven's Progressive Matrices (Raven, 1958) and Sequential Tests of Educational Progress Level 4A computation subtest (Educational Testing Service, 1970). Based on a bivariate plot of their scores on these two tests, students were placed into a high, medium, or low ability category. Within each of these categories, students were randomly assigned to one of four classes. Classes were randomly assigned to teacher and treatment. The resulting class sizes were 32 and 28 for the small-group variation, and 29 and 28 for the direct instruction approach.

Students in the small-group variation were further assigned to small groups of four students that varied in math ability, as determined from the bivariate plot. Each small group was composed of one high ability student, two medium ability students, and one low ability

student.

Placing students into new groups was not novel for the teachers and students in this study. The students typically had a different teacher for each subject, and students were often regrouped so their classes had a different composition for each subject.

Instrumentation

The students had been taught math in homogeneous ability groups based on a district math objectives test. For the purposes of this study, students were taught with two teaching approaches that differed from the regular approach used, and students were taught a unit on common fractions from Developing Mathematical Processes (Romberg, Harvey, Moser, & Montgomery, 1976), which was not their regular curriculum.

Before instruction began, students completed the following aptitude measures: the mathematical computation subtest of the Sequential Tests of Educational Progress (STEP) Level 4A (Cronbach's α reliability coefficient = .87, test publisher's α = .91); the Raven's Progressive Matrices (α = .90, test publisher's α = .88); the Academic Achievement Accountability (AAA) locus of control questionnaire by Clifford (1976) (α = .86); an attitude toward math scale (α = .92); and a preference for learning in small groups scale (α = .63).

The 18-item AAA questionnaire was used in its original form. Items 1, 3, 4, 6, 7, 8, 10, 11, 12, 14, 17, and 18 indicated internal academic locus of control if answered positively. The remaining items indicated internal academic locus of control if answered negatively. The responses "YES," "yes," "?," "no," and "NO" were scaled from 1-5.

or 5-1 according to the direction of the item. The composite score was the total on all 18 items. A high score on this scale indicated that the student felt accountable for his or her school performance. Conversely, a low score indicated that the student attributed school performance to luck, chance, and fate.

The children's attitude toward math was measured by a 15-item questionnaire developed by Peterson and Janicki (1979), adapted from the Science Attitude Inventory by Klausmeier, DiLuzio, and Brumet (Note 3). The attitude scale had a 5-point Likert response format ranging from "strongly agree" to "strongly disagree."

The preference for learning in small groups questionnaire consisted of eight items developed by Peterson and Janicki (1979). For each item, the student was asked to choose either a sentence describing a small-group approach math class or a direct approach. For example, "I would most like a math class where ... (a) most all the teaching is done by the teacher, or (b) kids spend a lot of time teaching each other."

After completion of the 2-week unit on fractions, student achievement was assessed with a test on fractions developed by Peterson and Janicki (1979) which was adapted from a test included as part of the curriculum unit (Romberg et al., 1976). The test required the students to do computational problems and solve story problems with fractions. Two weeks after their math instruction the students were readministered the same test to measure their retention of the math concepts. Cronbach's α was .93 for the immediate test and .93 for the retention test. The correlation between the two tests was .89 which

could be considered a measure of test-retest reliability.

At the end of the unit, students also completed an attitude toward math posttest (α = .90) and an attitude toward teaching approach questionnaire (α = .89). The attitude toward math posttest was the same test that had been administered as a pretest. The attitude toward teaching approach scale was developed by Peterson and Janicki (1978) and consisted of eight items. The scale consisted of items like, "I like the way my teacher taught math class." Responses ranged from "strongly agree" to "strongly disagree."

An observation instrument was used to measure student behaviors and teacher instructional behaviors. Seven teacher and class behavior categories were included to assess fidelity of treatment implementation. Student behaviors were divided into eight categories that attempted to document student reactions to the instructional treatments.

The observation system required the observers to code the behaviors of the teacher, the class, and individual students. All students were coded each day of the study. The class was divided into groups of four students for coding purposes, and the observer coded each student in the group separately for 6 minutes a day. The group of four students coded in the small-group variation was equivalent to the student work groups, but in the direct approach the group of four students coded referred to one row of students. Observers began coding with a different group each day. Therefore, each student was observed at various times during the class period. Every 20 seconds the observers checked at least one category for each of the four students and at least one

category for the teacher and the class.

The generalizability of the observations was assessed following the procedure outlined by Cronbach, Gleser, Nanda, and Rajaratnam (1972). The generalizability analyses were done with BMD: Biomedical Computer Programs (Dixon, 1971). Since the two classes occurred simultaneously, one of two observers coded each class for 1 week, and then switched to coding the other class. A third coder was used to determine the generalizability of the observation data. An estimate of the generalizability of the observations across raters was obtained by having two coders observe each of the four classes once. Since two sets of two coders were used, two estimates of generalizability for each observation category (ρ) were calculated. The estimated generalizability coefficients (ρ) were as follows: student is off-task (ρ = .65, .57); teacher reviews (ρ = .98, .98); teacher lectures (ρ = .82, .99); teacher asks question of student (ρ = .97, .92); teacher use of controlled practice (no instances of this category were detected by one set of observers) (ρ = .95); class works in small groups (ρ = .97, .99); class works individually (ρ = .99, .99); and teacher monitors seatwork activity (ρ = .94, .95).

Procedure

Two weeks before the teaching began, the experimenter met with the teachers to discuss the curriculum unit and teaching approaches. At this meeting, the experimenter stated the prerequisites to the fraction unit so the teachers would make sure that all the participating students

had the necessary prerequisites before the start of the study. The experimenter discussed the objectives, content, and activities of the unit and gave each teacher a copy of the manual on the direct instruction approach written by Good et al. (Note 1). Table 1 presents a summary of the key instructional behaviors given in this manual.

The experimenter met with the teachers again the next week to review the instructional approaches. The teachers and investigators discussed the features of each approach, particularly those features that differentiated them. Special emphasis was given to teachers' monitoring of the small groups in the small-group variation. The teacher then wrote detailed lesson plans for the 9 days of instruction for the two approaches. Much time was spent discussing these lesson plans. The various activities planned for the two instructional approaches differed, but the content remained the same.

Before the study began, the students were informed about the study and told they were to be tested. The aptitude measures were given to the students during their math classes on 2 consecutive days.

The students in the direct approach were assigned seats so observers could accurately code the classroom interaction. The class was then taught the fractions unit using the direct instruction approach for 55 minutes a day for the 9 days of the study. The teacher proceeded as follows: The teacher spent the first part of the class in a whole-group setting, reviewing new concepts by using explanations, asking questions, and having the students work on short problems. Once the teacher had decided that the majority of the class understood

Table 1

Summary of Key Instructional Behaviors in Direct Instruction Approach

[From Good, Grouws, Beckerman, Ebmeier, & Flatt (Note 1)]

Daily review (first 8 minutes except Mondays)

a) review the concepts and skills associated with the homework

b) collect and deal with homework assignments

c) ask several mental computation exercises

Development (about 20 minutes)

a) briefly focus on prerequisite skills and concepts

b) focus on meaning and promoting student understanding by using lively explanations, demonstrations, process explanations, illustrations, etc.

c) assess student comprehension

1) using process/product questions (active interaction)

2) using controlled practice

d) repeat and elaborate on the meaning portion as necessary

Seatwork (about 15 minutes)

a) provide uninterrupted succesaful practice

b) momentum--keep the ball rolling--get everyone involved, then sustain involvement

c) alerting--let students know their work will be checked at end of period

d) accountability--check the students' work

Homework assignment

a) assign on a regular basis at the end of each math class except Fridays

b) should involve about 15 minutes of work to be done at home

c) should include one or two review problems

Special reviews

a) weekly review/maintenance

1) conduct during the first 20 minutes each Monday

2) focus on skills and concepts covered during the previous week

the concept, she assigned seatwork. Each student worked on the workbook by him- or herself. The teacher walked around the room, monitored the students' work, and gave individual help when needed. The teacher gave the students a written homework assignment every other night. The homework included any unfinished seatwork plus some new problems. During the next day's review session, the teacher and students discussed the homework and assigned seatwork from the previous day.

The students in the small-group variation were assigned to groups on the first day of teaching. The teacher then told the students what was expected of them in their small-group work. The teachers said that the group was to work as a team in solving the workbook assignments. She said that students could talk and get help from the group members as needed. The first part of the day's instruction was spent in a whole-group format. The teacher reviewed previous concepts and went over the homework assignment. Some of this review was reserved for the students to discuss in their small groups. The teacher then developed new concepts by using explanation, asking questions, and having students work on short problems. The teacher then gave the seatwork assignment, and the students began work in their small groups. The teacher monitored the group work but explained that the students should ask others in their group for help before seeking out the teacher. The teacher wrote the homework assignment on the board so that groups finishing early would have the option of doing their homework. The teacher also gave groups the option of playing math games after they had completed their seatwork, but the groups seldom played the games.

Math was taught at the same time every day from 10:35 a.m. to 11:30 a.m. Two classes participated in the study during the first 2-week session, and two classes participated during the second 2-week session. One teacher taught the direct approach, and the other taught the small-group variation during the first session. The teachers switched approaches for the second session. The teachers taught the approaches in a different order to counterbalance any possible effects associated with the teachers becoming more familiar with the curriculum unit.

At the end of the 9-day unit, students completed the attitude toward math scale, the attitude toward approach scale, and the 35-item fractions test. This same fractions test was given to the students 2 weeks later to measure retention. The students were not informed of the correct answers between the immediate and delayed test.

Results

Fidelity of Implementation of Teaching Approaches

Table 2 presents the mean number of minutes spent per day on each teacher and class category. The total minutes spent do not sum to 55 (the typical class length) because more than one category may have been coded during a single coding interval.

The means in Table 2 indicate that the teaching approaches differed as intended. Students in the direct approach did their work individually and did not spend time in small group work. On the other hand, the students in the small-group variation did all their seatwork in small groups. But the results in Table 2 also indicate that teacher 1 differed from teacher 2 in her implementation of the direct approach. Teacher 1 spent much less time reviewing in the direct approach than did teacher 2 and somewhat less time reviewing than did either teacher in the small group variation. Similarly, teacher 1 spent much less time on maintenance of seatwork--monitoring students while they worked--in the direct approach than she did in the small group variation and slightly less time than teacher 2 spent on maintenance. Finally, teacher 1 spent more time lecturing in the direct approach than she did in the small-group variation and more time than the other teacher spent lecturing in both approaches.

Descriptive Statistics on Aptitudes and Outcomes

Table 3 shows the means and standard deviations of the aptitude

Table 2

Mean Number of Minutes Spent Per Day in the Observation Categories for Teacher and Class in the Four Classes

(Standard Deviations in Parentheses)

	Small-group variation		Direct instruction	
Class of teacher:	1	2	1	2
Observation category	(N = 26)	(N = 32)	(N = 27)	(N = 29)
Reviews	13.3	10.6	7.4	17.1
	(8.7)	(8.4)	(4.7)	(14.4)
Lectures	15.5	13.0	19.8	15.1
	(8.4)	(9.5)	(7.6)	(7.7)
Teacher asks question	5.8	9.1	8.7	9.0
	(4.1)	(8.8)	(3.9)	(5.2)
Use of controlled practice	.1	2.3	2.5	1.3
	(.2)	(4.6)	(2.2)	(1.3)
Small group work	20.1	17.2	0	0
	(9.1)	(5.9)	(0)	(0)
Individual work	0	0	13.4	15.7
	(0)	(0)	(10.4)	(5.9)
Teacher maintenance of seatwork	17.9	14.3	10.8	12.3
	(8.9)	(5.6)	(8.4)	(6.5)

Table 3

Means and Standard Deviations of Aptitudes and Outcomes (Standard Deviations in Parentheses)

	Small-group		Direct	
Class of teacher:	1	2	1	2
Variable	(N = 26)	(N = 32)	(N = 27	(N = 28)
STEP-math computation	40.57	41.44	40.63	41.52
	(8.32)	(8.27)	(9.64)	(7.88)
Raven's Progressive Matrices	37.48	37.69	40.19	38.04
	(9.31)	(9.38)	(8.09)	(8.43)
Attitude toward math pretest	49.83	50.66	45.70	47.93
	(8.59)	(10.73)	(12.14)	(11.21)
Locus of control	69.91	71.25	66.44	71.64
	(8.27)	(10.62)	(12.96)	(8.50)
Preference for learning in small groups	4.04	4.06	3.86	3.96
	(2.25)	(2.20)	(1.98)	(2.17)
Achievement posttest	23.65	23.66	19.85	27.75
	(9.66)	(9.71)	(9.41)	(9.05)
Retention test	23.22	22.44	20.48	26.57
	(9.10)	(9.51)	(10.14)	(9.43)
Attitude toward math posttest	42.52	45.41	42.30	43.86
	(8.84)	(11.06)	(12.06)	(9.72)
Attitude toward teaching approach	20.13	30.03	23.59	30.93
	(8.06)	(5.60)	(6.72)	(5.11)

and outcome scores of students in all classes. Means and standard deviations of the aptitude scores were similar across the four classes. Students' attitude toward math decreased between pre- and posttest in all four classes. In all classes the average score on the immediate and delayed test was about the same. Students' scores on STEP-math computation were moderately correlated with scores on Raven's Progressive Matrices (r = .41). The students' scores on attitude toward math pretest were correlated with scores on the locus of control measure (r = .50). Scores on the immediate achievement test were highly correlated with scores on the retention test (r = .89).

Principal-Component Analysis of Aptitudes

The problem of multicollinearity can arise when the independent variables are intercorrelated in a regression analysis. To create predictor variables that were orthogonal in the total sample, we performed a principal-component analysis on the aptitude variables. Varimax rotation was used, and two factors were created. The first factor was primarily attitude toward math and, to a lesser extent, locus of control. Attitude toward math and locus of control loaded .94 and .52, respectively, on factor one. The second factor was an ability factor similar to the ability factor in the Peterson and Janicki (1979) study. Raven's Progressive Matrices and STEP-math computation loaded .68 and .59, respectively, on this second factor. These two factors were used in the regression analyses. Since group preference did not load on either factor, it was entered separately in the regression analyses.

Aptitude-Treatment Interactions (ATI)

According to Cronbach and Snow (1977), regression analysis is the

preferred approach to analyzing ATI data. However, no one regression technique has been determined to be best. Cronbach and Snow recommended using a hierarchical procedure for adding predictors to the equation. More recently, Cronbach (Note 4) and Price (Note 5) have recommended a simultaneous procedure in which the variance accounted for ($\underline{R}^2$) and $\underline{F}$ ratios for a predictor or group of predictors are calculated by stepping down from the full regression model to a model without that variable or group of variables in the equation. A version of this second approach was used in our analyses.

Two sets of predictors were included in the primary regression equation. These were: (a) aptitudes, teacher, and treatment effects; and (b) aptitude-treatment interactions. Effect codings (1 and -1), as described by Kerlinger and Pedhazur (1973), were used for treatments as well as for teachers. Deviation scores were used for the aptitudes to eliminate artificial correlations between a particular variable and interaction terms involving the variable. The aptitudes were the two factor scores mentioned previously, preference for group, and the ability factor squared. The ability factor squared term was included to see if there were any curvilinear trends in the data. Teacher, treatment, and teacher x treatment terms were also included. The teacher term was included as a covariate to reduce error variance and check for possible teacher effects. All first-order ATI were entered along with the $(\text{ability})^2$ x treatment term. Previous research has shown significant ATI for $(\text{ability})^2$ (Webb, Note 6). Scores for $(\text{ability})^2$ were made orthogonal to ability using orthogonal polynomials (see, for

example, Kendall & Stuart, 1967) so that the regression coefficient for ability would represent the linear effect of ability and would not be changed by the addition of the quadratic term.

A simultaneous procedure, as described above, was used to test aptitudes, treatments, and ATI. Each aptitude or treatment term was tested by stepping down from a regression model, including aptitudes and treatments only, to a model without that term in the equation (see Serlin, Note 7). Each ATI term was tested against the full model.

The numerator of the F ratio was the R^2 due to the variable or group of variables being tested divided by the number of terms being tested. The denominator was 1 minus the proportion of variance predicted by the full model divided by $N - k - 1$ degrees of freedom, where N equals the number of subjects and k equals the number of terms in the full model (e.g., Kerlinger & Pedhazur, 1973, p. 251).

Achievement and Retention

Table 4 shows the results of regression analyses on achievement and retention scores. As indicated in Table 4, the full regression equation accounted for 52.2% of the variance in immediate achievement scores. The ability factor accounted for more variance than any other predictor with ΔR^2's equal to .31. $(\text{Ability})^2$ accounted for 4.6% of the variance. A significant teacher effect accounted for 4.9% of the variance, and a significant teacher by treatment interaction predicted 6.9% of the variance. Finally, a significant ATI appeared for the attitude/locus of control factor.

The regression equation for each treatment was computed from the

Table 4

Summary of Generalized Regression Analyses on Achievement and Retention Scores

Variable in regression	Achievement			Retention		
	df	R^2	F	df	R^2	F
Aptitudes						
Ability	1	.308	55.55***	1	.391	78.97***
Attitude/locus of control	1	.001	.12	1	.000	.01
Preference	1	.000	.03	1	.000	.08
$(Ability)^2$	1	.046	8.30***	1	.042	8.51***
Teacher and treatments						
Teacher	1	.049	8.82***	1	.025	5.08**
Treatment	1	.000	.06	1	.000	.00
Model including aptitudes, teacher and treatment	6	.428	12.86***	6	.490	16.50***
Residual	103	.572	--	103	.510	--
Teacher x treatment	1	.069	14.22***	1	.060	12.37***
ATIs						
Ability x treatment	1	.002	.33	1	.007	1.57
Attitude/locus of control x treatment	1	.021	4.23**	1	.010	2.18
Preference x treatment	1	.002	.43	1	.003	.67
$(Ability)^2$ x treatment	1	.003	.63	1	.001	.31
Full model	11	.522	9.73***	11	.560	11.36***
Residual	98	.478	--	98	.440	--

*$p < .10$; **$p < .05$; ***$p < .01$.

unstandardized regression coefficients. These equations are shown in Table 5. These equations were then used to graph the relationship between attitude/locus of control and math achievement shown in Figure 1.

An extension of the Johnson-Neyman technique by Potthoff (1964) was used to determine regions of significance between the two approaches.[2] In this procedure, regions of significance between the two approaches are different simultaneously for all points contained in it. Cronbach and Snow (1977) state that "When the confidence level $(1 - \alpha)$ is set at .90 and N per treatment is below 100, the region of uncertainty

---

[2]The following formula, which is equivalent to Potthoff's formula, was used to determine the region of significance:

$$(r + 1)\, F_{r+1,\, f};\ \alpha = \frac{[(\hat{\alpha}_2 - \hat{\alpha}_1) + (\hat{b}_2 - \hat{b}_1)\, X]^2}{[V_1(X) + V_2(X)]\, S_e^2}$$

where:

$\hat{\alpha}_2$ and $\hat{\alpha}_1$ are the intercepts of the two regression lines;

$\hat{b}_2$ and $\hat{b}_1$ are the slopes of the two regression lines;

X is the specific value of the aptitude variable that is of interest;

r is the number of predictors being tested;

f is the total of the residual degrees of freedom for the two regressions;

S_e^2 is the error mean square with F degrees of freedom; and

$V(X)_i = X_o'(X'X)^{-1}X_o$ where

$X_o' = (1, X_{10}\ X_{20}, \ldots)$ is a specified set of points.

Table 5

Regression Equations for the Different Treatments

Dependent variable and treatment	Constant	b for ability	b for attitude/loc	b for preference	b for (ability)^2	b for teacher
Achievement test						
Direct instruction	20.41	8.21	-1.26	.34	4.39	-4.49
Small-group variation	22.16	7.11	2.01	-.11	2.79	-.03
Retention test						
Direct instruction	19.67	9.62	-1.22	.20	3.72	-3.96
Small-group variation	22.94	7.39	1.02	-.34	2.65	-.69
Attitude toward math						
Direct instruction	44.44	.93	8.87	-.37	2.17	-.05
Small-group variation	43.58	.85	9.27	-.15	-.74	-1.07
Attitude toward approach						
Direct instruction	26.73	-.18	.56	.31	-1.00	-3.48
Small-group variation	25.43	-.48	1.93	.01	-1.32	-4.92

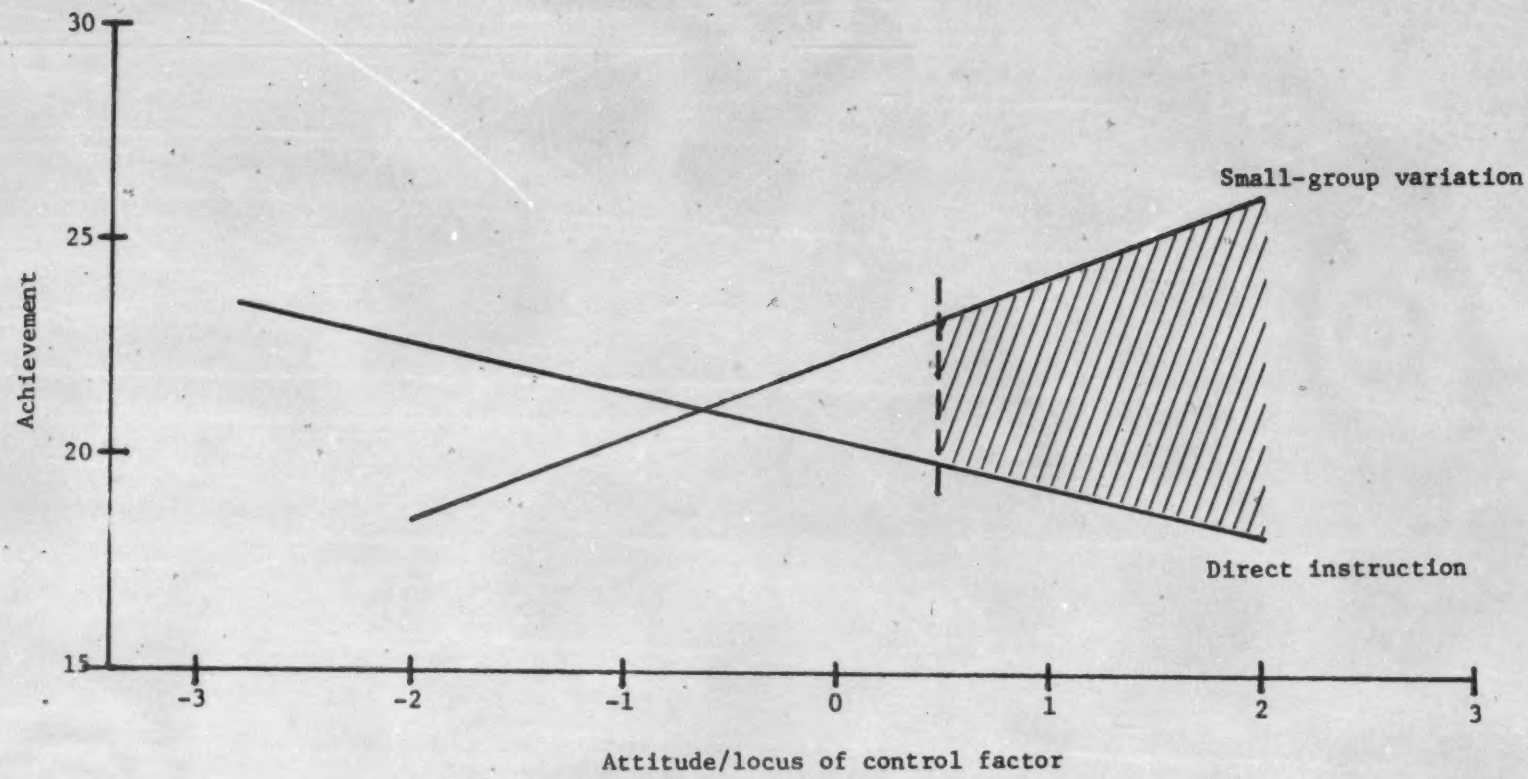

Figure 1. Regression of Achievement on Attitude/Locus of Control Showing ATI [Area to the right of the dotted line indicates the region of significance using Potthoff's (1964) extension of the Johnson-Neyman technique.]

is likely to extend over the entire X continuum" (p. 90). For this reason, an overall α was set at .30 and each of three ATI was tested as a planned comparison at the .10 level. Using this criterion, a region of significance ($X > .45$) was identified (see Figure 1). Students with scores greater than .45 on the attitude toward math/locus of control factor (35.5% of the students) performed significantly better in the small-group variation than in direct instruction. The achievement of students with factor scores less than .45 did not differ significantly in the two approaches.

The results of the regression analysis for the retention test were nearly identical to those for the immediate achievement test. (See Tables 4 and 5.) However, the percent of variance accounted for by teacher, treatment, and ATIs decreased while the percent of variance accounted for by the ability factor increased. The variance accounted for by the interaction between treatments and the attitude/locus of control factor decreased from the immediate to the retention test and was not statistically significant.

Attitude Toward Math and Toward Teaching Approach

The results of the regression analyses on the attitude posttests are presented in Table 6, and the regression equations are shown in Table 5. The full regression model accounted for 72.2% of the variance in scores on the attitude toward math scale. Of this 72.2% variance accounted for, the majority of it (57.6%) was contributed by the attitude toward math/locus of control factor. No other aptitude was significant, nor were any of the effects due to teacher or treatment,

Table 6

Summary of Generalized Regression Analyses on Attitude Measures

Variable in regression	Attitude toward math			Attitude toward approach		
	df	R^2	F	df	R^2	F
Aptitudes						
Ability	1	.004	1.51	1	.001	.20
Attitude/locus of control	1	.576	203.48***	1	.017	2.65
Preference	1	.002	.87	1	.001	.21
$(Ability)^2$	1	.002	.76	1	.009	1.48
Teacher and treatment						
Teacher	1	.002	.65	1	.289	45.68***
Treatment	1	.005	1.82	1	.026	4.10**
Model including aptitudes, teacher and treatment	6	.708	41.68***	6	.348	9.18***
Residual	103	.292	--	103	.652	--
Teacher x treatment	1	.002	.80	1	.009	1.34
ATIs						
Ability x treatment	1	.000	.00	1	.000	.03
Attitude/locus of control x treatment	1	.000	.09	1	.006	.92
Preference x treatment	1	.001	.15	1	.002	.24
$(Ability)^2$ x treatment	1	.009	3.09*	1	.000	.03
Full model	11	.722	23.08***	11	.370	5.23**
Residual	98	.282	--	98	.630	--

*p < .10; **p < .05; ***p < .01.

but the curvilinear ATI for ability was significant. Regions of significance were computed for this ATI using the procedure described above. These regions are shown in Figure 2. Students who had ability scores between -1.64 and -1.0 had significantly more positive attitudes toward math in direct instruction than in the small-group variation. Students who had ability scores between 1.0 and 1.64 also had significantly more positive attitudes in direct instruction than in the small-group variation. Medium ability students with ability scores between -1.0 and 1.0 did not differ significantly in their attitudes toward math in the two treatments.

Students' attitude toward the teaching approach was best predicted by the teacher they had. (See Tables 5 and 6.) The teacher effect explained 28.9% of the variance in attitude toward approach while the full regression model accounted for only 37.0% of the variance.

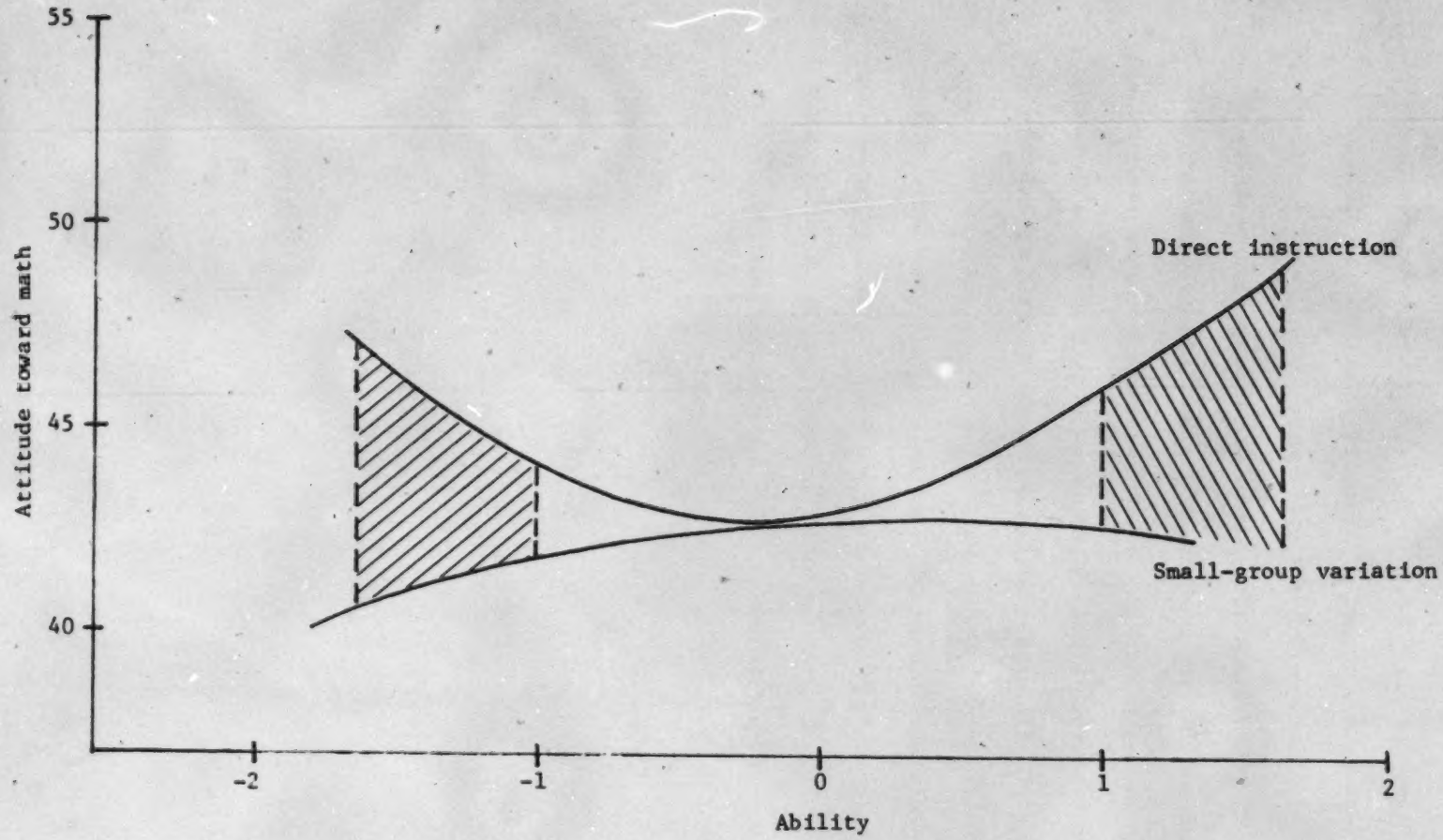

Figure 2. Regression of Attitude toward Math on Ability Showing ATI [Shaded areas indicate the regions of significance using Potthoff's (1964) extension of the Johnson-Neyman technique.]

Discussion

The results of the present study support the recent findings of Ebmeier and Good (1979) that the effectiveness of direct instruction depends on the type of student. Ebmeier and Good found that in educated/secure teachers' classes, high achieving/task-oriented students did worse in direct instruction than in the control teachers' classes. These students were high on prior achievement and low on external motivation. Similarly, in the present study, students who were high on an attitude/locus of control factor did worse in direct instruction than in a small-group variation of direct instruction. These students had more positive initial attitudes toward mathematics and were low on external locus of control (high on internal locus of control).

Thus, the effectiveness of direct instruction seems to depend on the students' sense of personal control. In direct instruction, learning is closely directed, monitored, and controlled by the teacher--the student actually has little control over instructional events. It's not surprising, therefore, that direct instruction would be effective for external students, who have a locus of control that matches the actual teaching situation, and detrimental for internal students, who may be frustrated in a situation where they have little control. In the present study, internal students may have benefited from the small-group variation because they believed they had greater control over their own learning by being given the choice of working on their homework

or playing math games in their small group.

A second significant finding was that high and low ability students had more positive attitudes toward math in direct instruction than in the small-group variation. The high ability students may have liked the individual seatwork because they could do the problems rapidly, and low ability students may have enjoyed doing the seatwork at their own pace and having the teacher available for help if needed. Medium ability students, on the other hand, did not differ in their attitudes in the two approaches. Because Ebmeier and Good (1979) did not examine students' attitudes, we can not compare our findings on this variable. However, our findings do support the results of other ATI studies which have shown that curvilinear ATI for ability may be important (see, for example, Webb, Note 6).

The results of the present study also lend support to Ebmeier and Good's (1979) conclusion that the effectiveness of direct instruction may depend on type of teacher. Ebmeier and Good found a significant interaction between teacher type and training in direct instruction versus no training in direct instruction. Within the trained group, there was a strong "teacher effect" that was not found in the control sample. In other words, type of teacher had a greater effect on student achievement within the group of teachers trained in direct instruction than within the untrained group. Ebmeier and Good traced the differential effectiveness within the trained group to differences in implementation of the behaviors in the direct instruction model. They concluded that, "The data suggest that teachers who implement the model

get good results, yet some teacher types choose to use more facets of the model than other teacher types" (p. 15).

A similar teacher effect appeared in the present study. Students' mean scores on the achievement and retention tests in the two teachers' classes differed significantly in the direct instruction approach but did not differ in the small-group variation (see Table 3). Within direct instruction, average student achievement in teacher 1's class was nearly 1 standard deviation lower than in teacher 2's class, and average student retention was approximately 2/3 of a standard deviation lower.

One explanation for this finding is that the effect of teacher is attenuated in the small-group variation because students are able to help one another and thereby compensate for poor teaching. Support for this explanation comes from anecdotal comments of the observers who noted that teacher 1's review and development was qualitatively poorer than teacher 2's review and development. The fact that the two teachers' small-group classes did not differ in achievement suggests that extensive student-student interaction may have compensated for poor teaching as well as cancelled out some effects of good teaching.

A second explanation is that differences in achievement between the direct instruction classes may be due to differences in teachers' implementation of the direct instruction approach and the subsequent effects on student behavior. For example, in the direct instruction approach teacher 1 spent an average of 7.4 minutes per day in review while teacher 2 spent 17.1 minutes. Furthermore, analysis of students'

off-task behavior indicated greater differences between the teachers' classes within the direct instruction approach than within the small-group variation. Within direct instruction, the mean number of intervals coded off-task for a student per day was 1.15 for teacher 1 and .60 for teacher 2 with standard deviations of 1.25 and .56, respectively. Within the small-group variation, the mean number of intervals for off-task was 1.05 for teacher 1 and .89 for teacher 2 with standard deviations of 1.12 and 1.08, respectively. A maximum of 18 intervals could have been coded off-task for a student per day.

These observation data suggest that teacher 2 implemented the direct instruction approach more effectively than teacher 1. Perhaps as Ebmeier and Good (1979) suggest, teachers are more likely to adopt and internalize ideas that are consonant with their existing beliefs, and the direct instruction approach was less consonant with teacher 1's beliefs than with teacher 2's beliefs.

On the other hand, perhaps teacher 1 needed additional training to implement the direct instruction approach. In the present study, teachers were given the training manual to read and study, and then they discussed the manual with the experimenter in a 1-hour training session. Although previous studies (Crawford & Stallings, Note 8; Berliner, Filby, Marliave, & Weir, Note 9) have shown this kind of "minimal" training to be more effective for training direct instruction than a "maximal" condition which includes workshops and extensive interaction with the experimenters, the extensiveness of training needed may depend on characteristics of the teacher. For example, a teacher

low in verbal ability may need more than a written manual to learn how to implement direct instruction. This may have been the case in the present study.

A competing hypothesis might be advanced to explain the "teacher effect" on achievement and retention in our study. The "teacher effect" may in fact, be a "practice effect." In the present study, the teacher x treatment interaction was confounded with the order in which the teachers taught the two approaches. Teacher 1 taught direct instruction during the first 2 weeks and the small-group variation during a second 2-week session. Teacher 2 taught the small-group variation the first 2 weeks and direct instruction the second 2 weeks. Both teachers were more effective the second session. However, we have not found a practice effect in other studies in which we employed a similar design with teachers switching approaches after the first 2-week session (see, for example, Peterson & Janicki, 1979; Peterson, Janicki, & Swing, Note 10). Furthermore, in a series of controlled experiments on "learning to teach," Clark, Snow, and Shavelson (1976) have shown that teachers do not become more effective with practice and, in fact, tend to become less effective after a second session. Thus, the existence of a practice effect does not seem to be the best explanation for the significant teacher x treatment interaction in the present study.

A fourth important finding was that there was no main effect of treatment on students' achievement, retention, and attitude toward math. However, students in the direct instruction approach did have a

significantly more positive attitude toward the teaching approach in direct instruction than in the small-group variation.

Although at first glance the findings from our study appear to contradict the proponents of the direct instruction approach who argue for its effectiveness in enhancing students' achievement, our findings actually complement their argument by elaborating the mechanism of direct instruction. This study has shown that limited student choice of activities within the direct instruction model and the use of small groups for seatwork, not for instruction, may be effective for some students. Furthermore, the degree of implementation and the effectiveness of direct instruction depend significantly on the teacher. Thus, the results of this study suggest that variations can and should be made within the direct instruction approach to meet the needs of individual students and, moreover, that training in direct instruction should be varied to meet the needs of individual teachers.

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